

EME Fundamentals

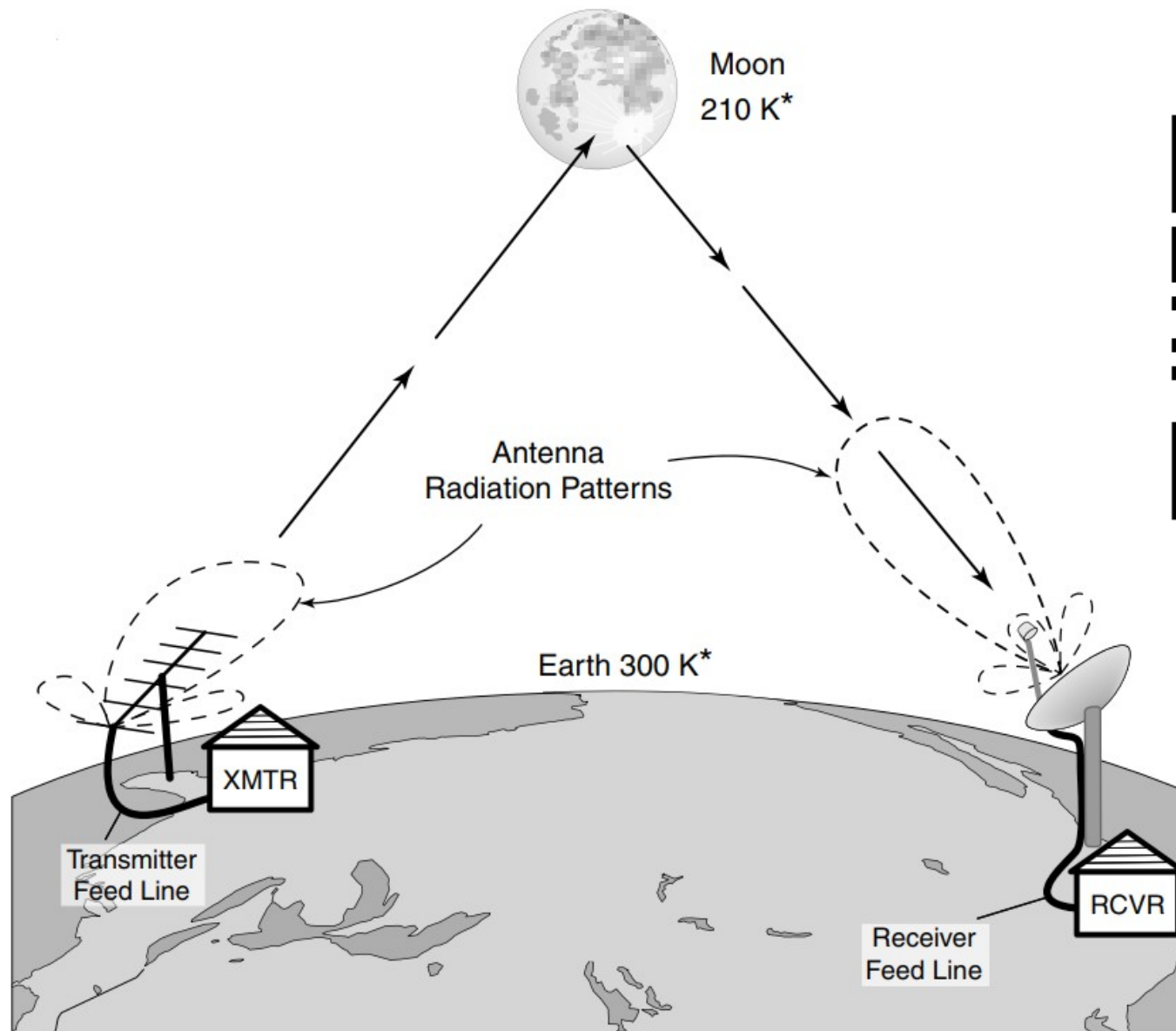
... from basic physics to digi-
modes...



Joe Taylor
K1JT

Overview

- EME fundamentals and limits
- Tweaking your setup
- Software and Digi-modes for EME

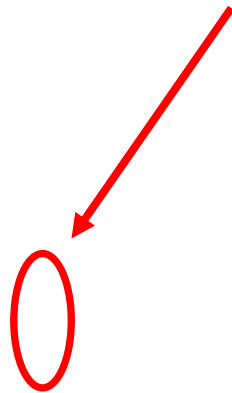


* Noise temperature, Kelvins



https://wsjt.sourceforge.io/Hbk_2010_Ch30_FME.pdf

EME Path Loss



Two-Way EME Path Loss with Isotropic Antennas

<i>Frequency (MHz)</i>	<i>Average Path Loss (dB)</i>
50	-242.9
144	-252.1
222	-255.8
432	-261.6
902	-268.0
1296	-271.2
2304	-276.2
3456	-279.7
5760	-284.1
10368	-289.2
24048	-293.5

Signal-to-Noise Ratio

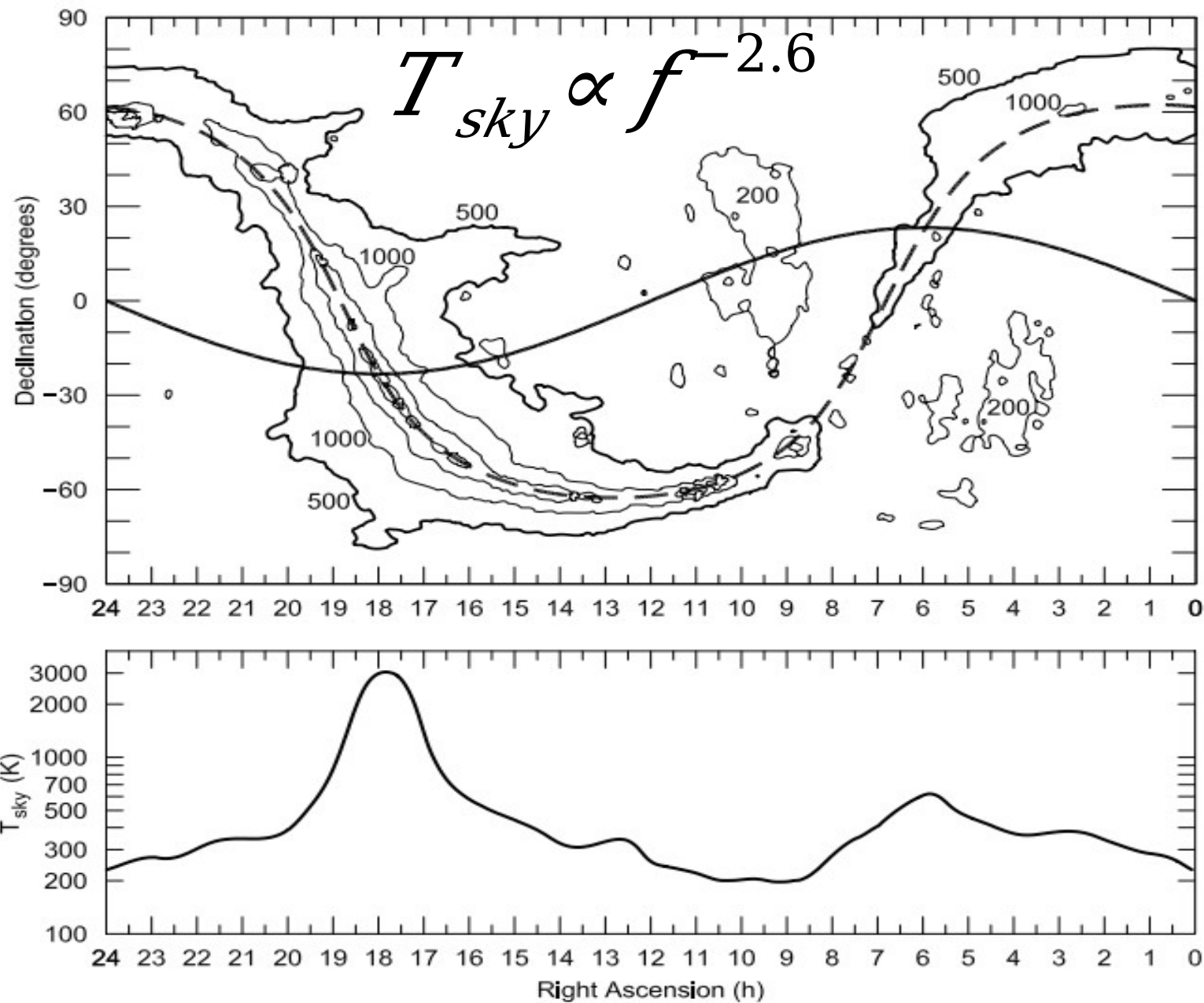
System noise
temperature

$$T_s = T_a + T_r$$

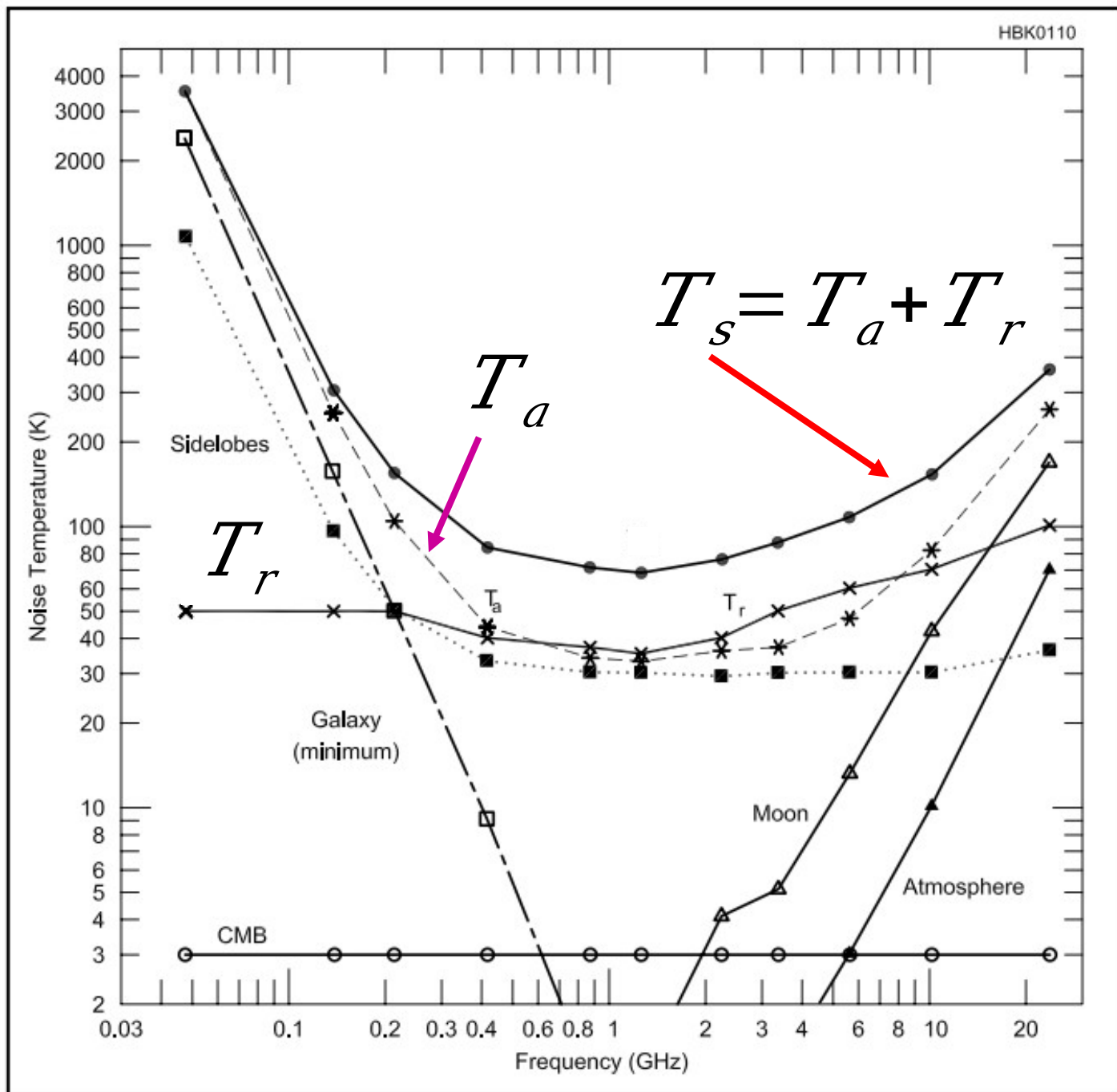
Received
bandwidth



Galactic
Noise
144
MHz



System Noise Temperature



Signal-to-Noise Ratio

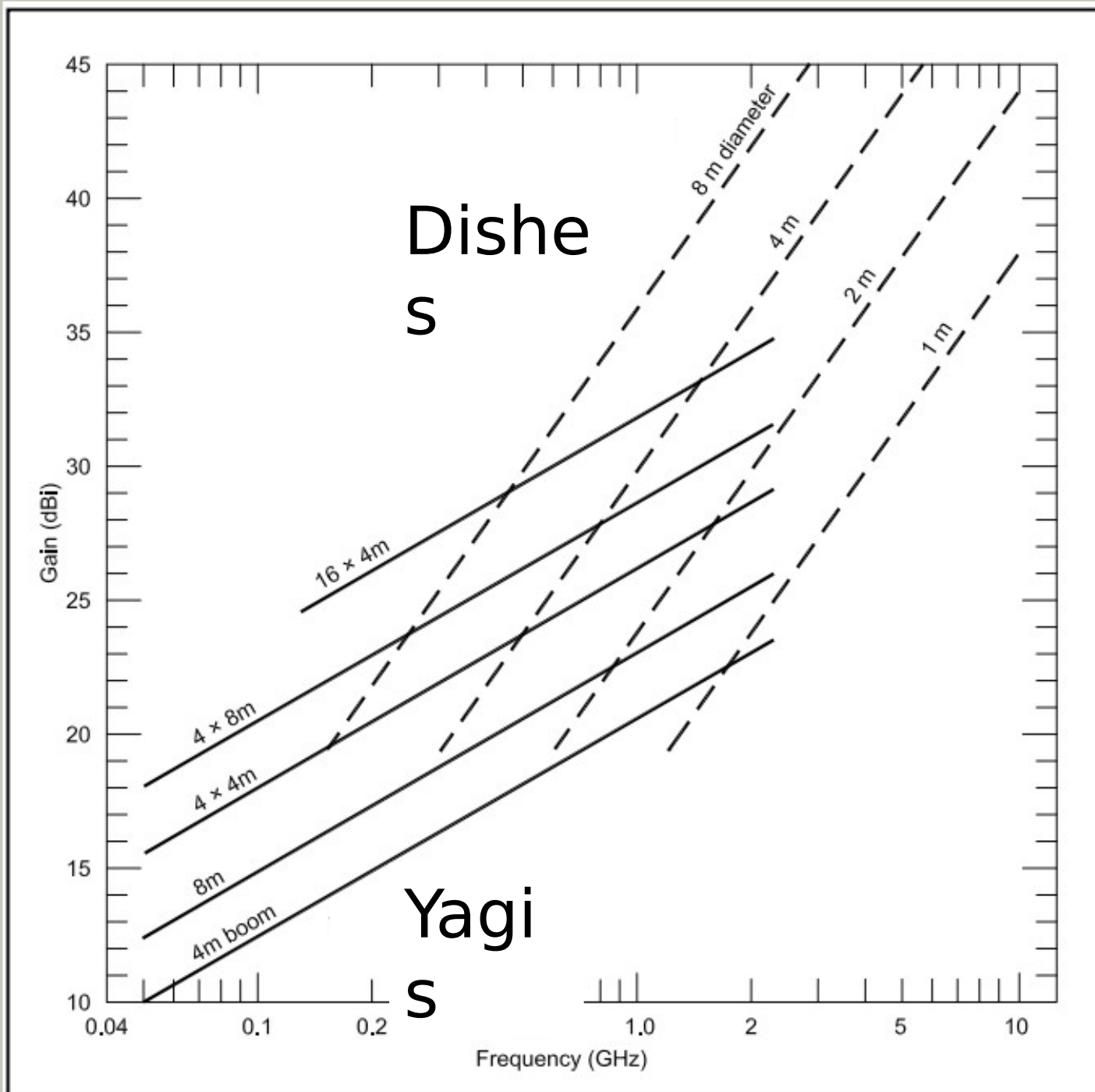
System noise
temperature

$$T_s = T_a + T_r$$

Received
bandwidth

Q: What can I control ??

What
type of
antenna
??



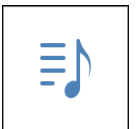
How much power ??

(Assume $S/N = 0$ dB, $B = 100$ Hz)

<i>Freq</i> (MHz)	<i>Ant</i> <i>Type</i> ¹	<i>G</i> (dBi)	<i>HPBW</i> (deg)	<i>TxPwr</i> (W)
50	4x12 m	19.7	18.8	1200
144	4x6 m	21.0	15.4	500
432	4x6 m	25.0	10.5	250
1296	3 m	29.5	5.5	160
2304	3 m	34.5	3.1	60
3456	2 m	34.8	3.0	120
5760	2 m	39.2	1.8	60
10368	2 m	44.3	1.0	25



0 dB



-15
dB

EMECalc by VK3UM

<https://www.vk5dj.com/doug.html>

Tx A (Home Station) W22Q_1296

Frequency	Path Loss	Rx BW	Diam	Mesh	Spacing	H ¹	Sys Sensitivity	Echo SN
1296 MHz	270.51 dB	10 K	2500 Hz	3.00 mm	10.00 mm		-145.3 dBm	-12.93 dB

Frequency: 1296 MHz Path Loss: 270.51 dB Rx BW: 10 K Diam: 3.00 mm Mesh: 10.00 mm Spacing: 10.00 mm H¹: Sys Sensitivity: -145.3 dBm Echo SN: -12.93 dB

Effective ground 258 K 0.90

Your last sfu data record has been loaded.

10.7cm 7.55 K 24.34 K <----- 21.38 K ----->

75	0.10 dB	0.35 dB	30.0 dB	12.6 dB	6.0 dB	21.16 K	0.41 K	12.01 dB
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Get sfu LNA Loss LNA Nf LNA Gair Coax Loss Rx Nf Spillover Feedthrough derived from Mesh size Sun Y

0.06 dB

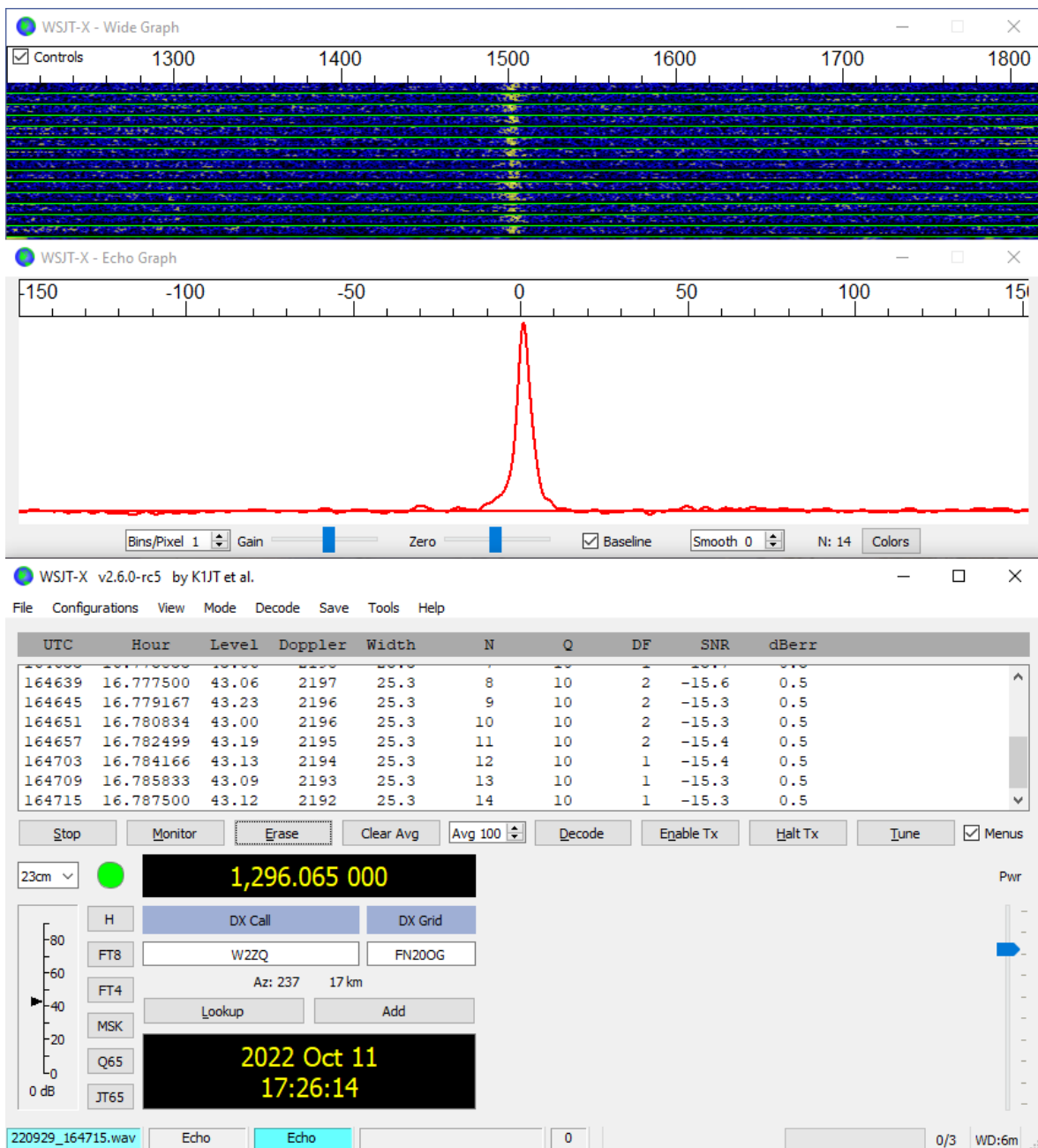
Tx A Output Power	Transmission Loss	Power at Feed	Moon Y
250 Watts	23.98 dBW	0.9 dB	203 Watts
		23.08 dBW	185,868 W EIRP

Ground Temperature 300 K 27 °C

RxTK 53.27 K = 0.73 dB
Receiver Noise Temperature

TSys 84.84 K = 1.11 dB
System Noise Temperature

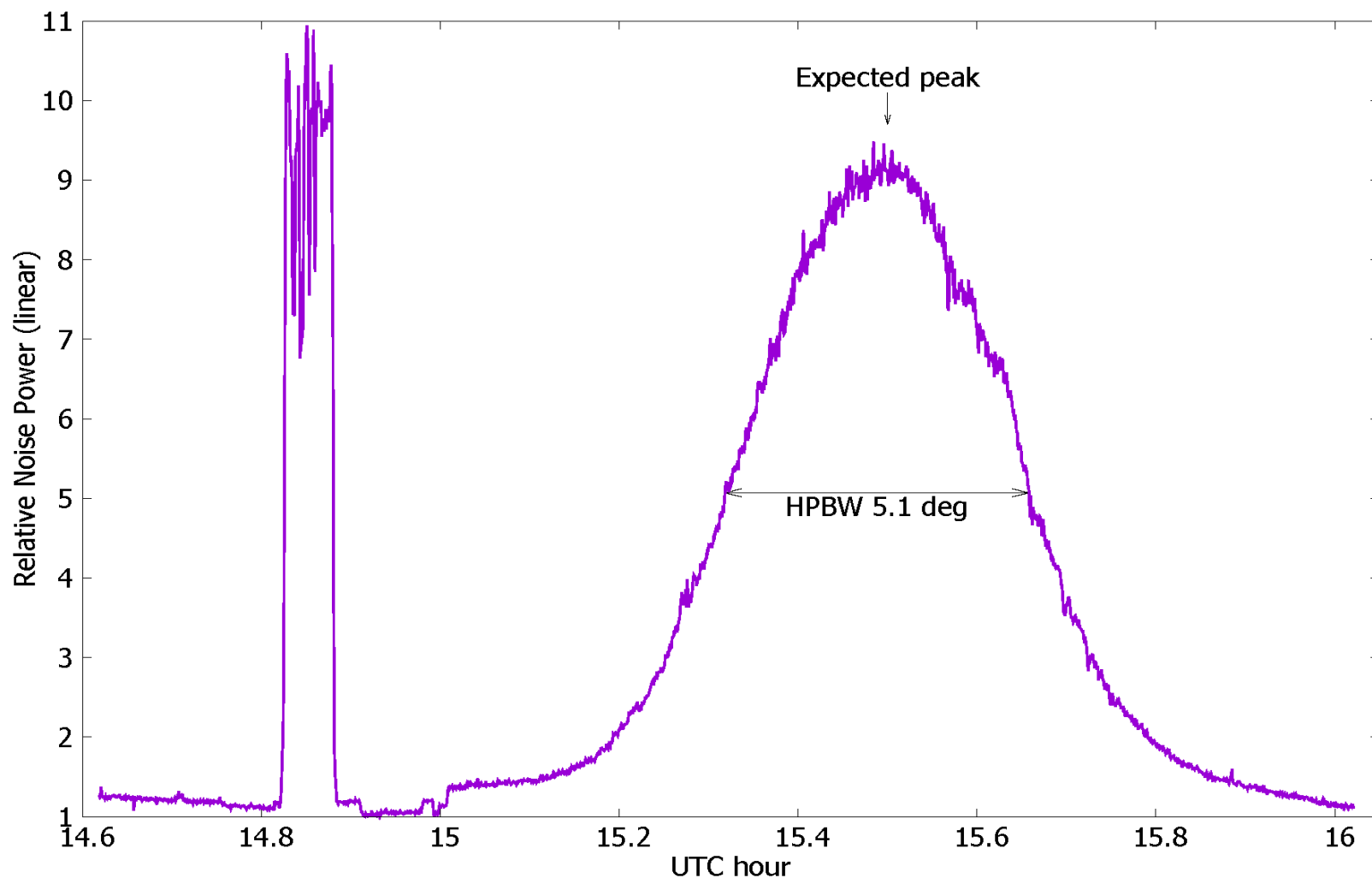
W2ZQ
EME echoes
SNR = -15.3
dB



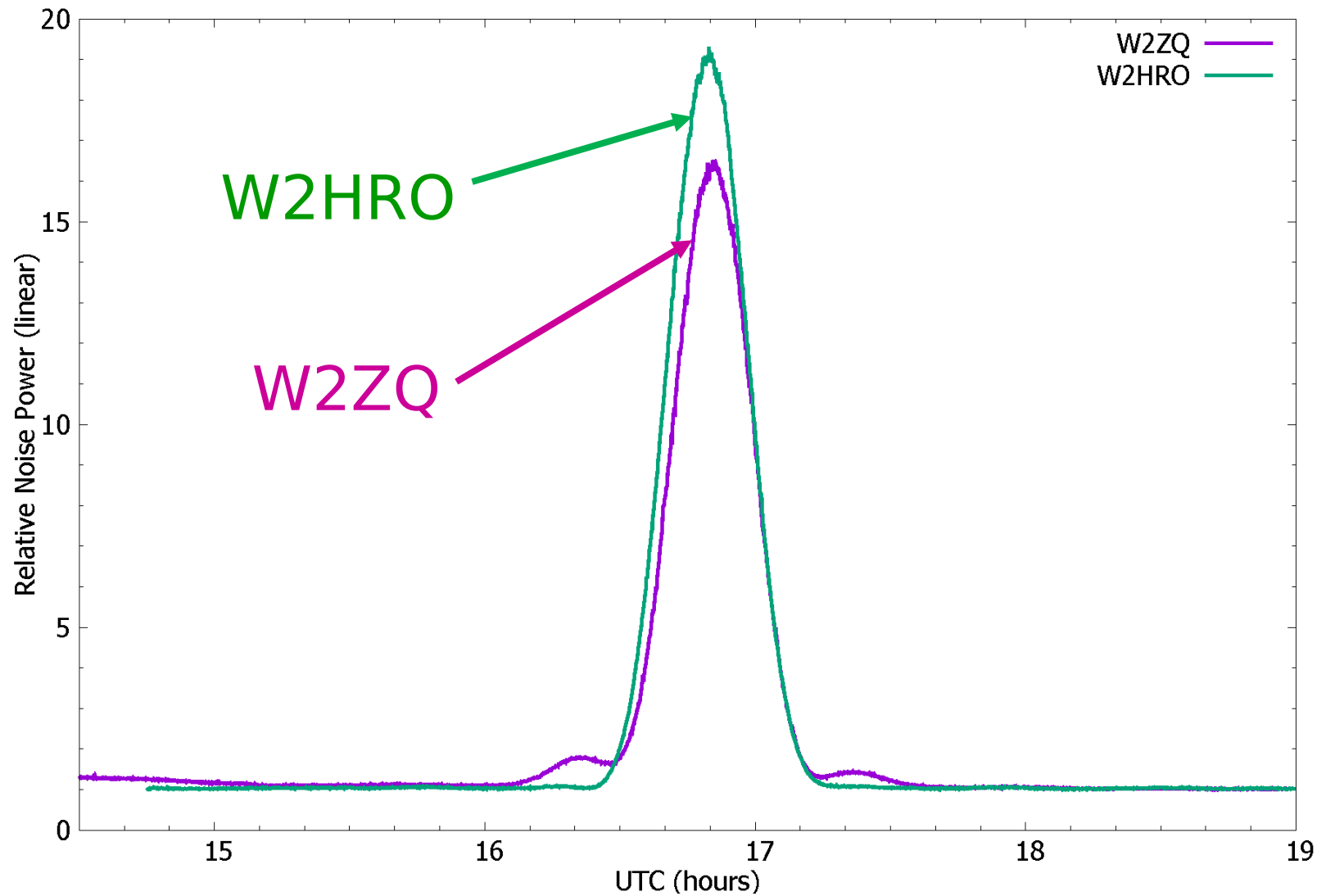
[https://wsjt.sourceforge.io/
wsity.html](https://wsjt.sourceforge.io/wsity.html)

Testing your setup...

W2ZQ: Sun Noise, 1296 MHz

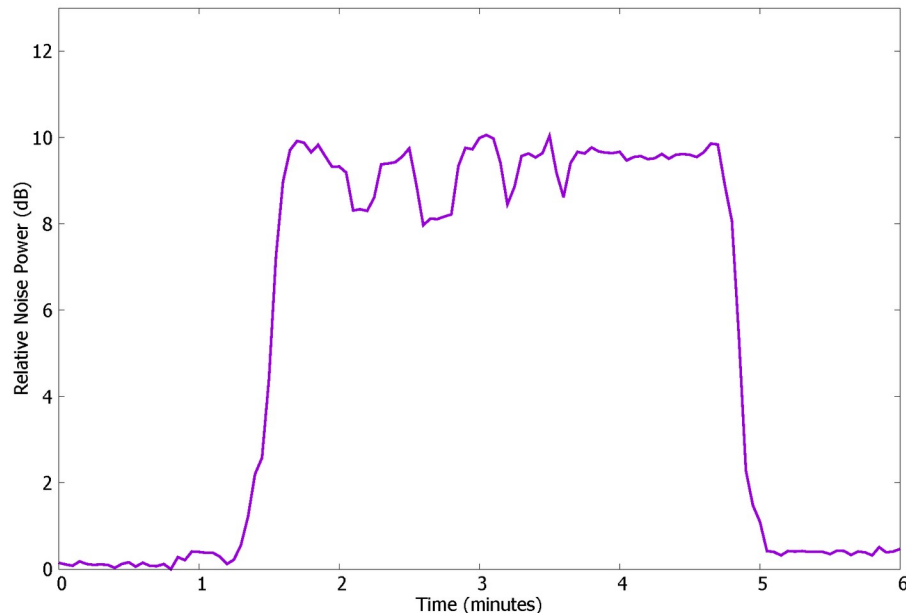


Antenna Pattern

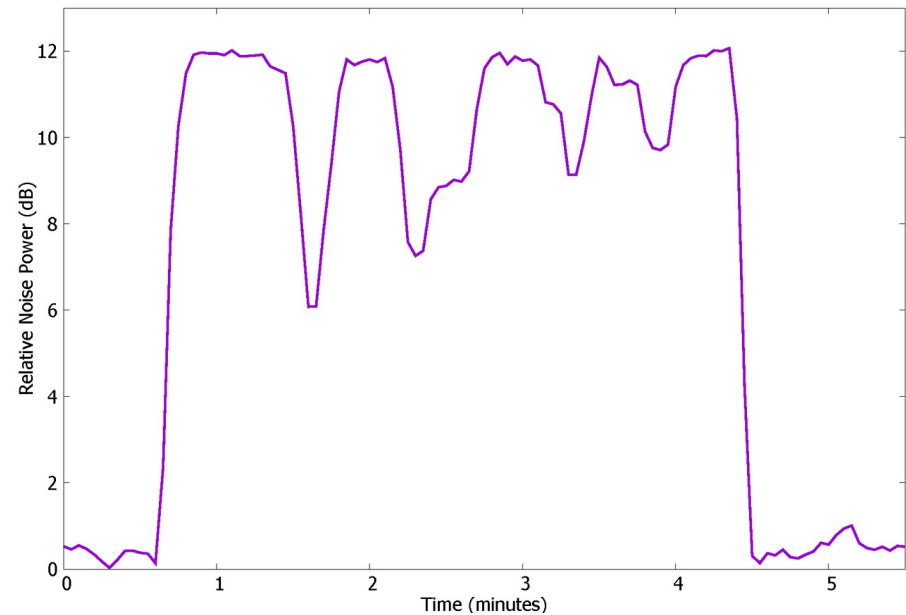


Focus Adjustment

Before: $Y_{\text{sun}} = 10$ dB



After: $Y_{\text{sun}} = 12$ dB



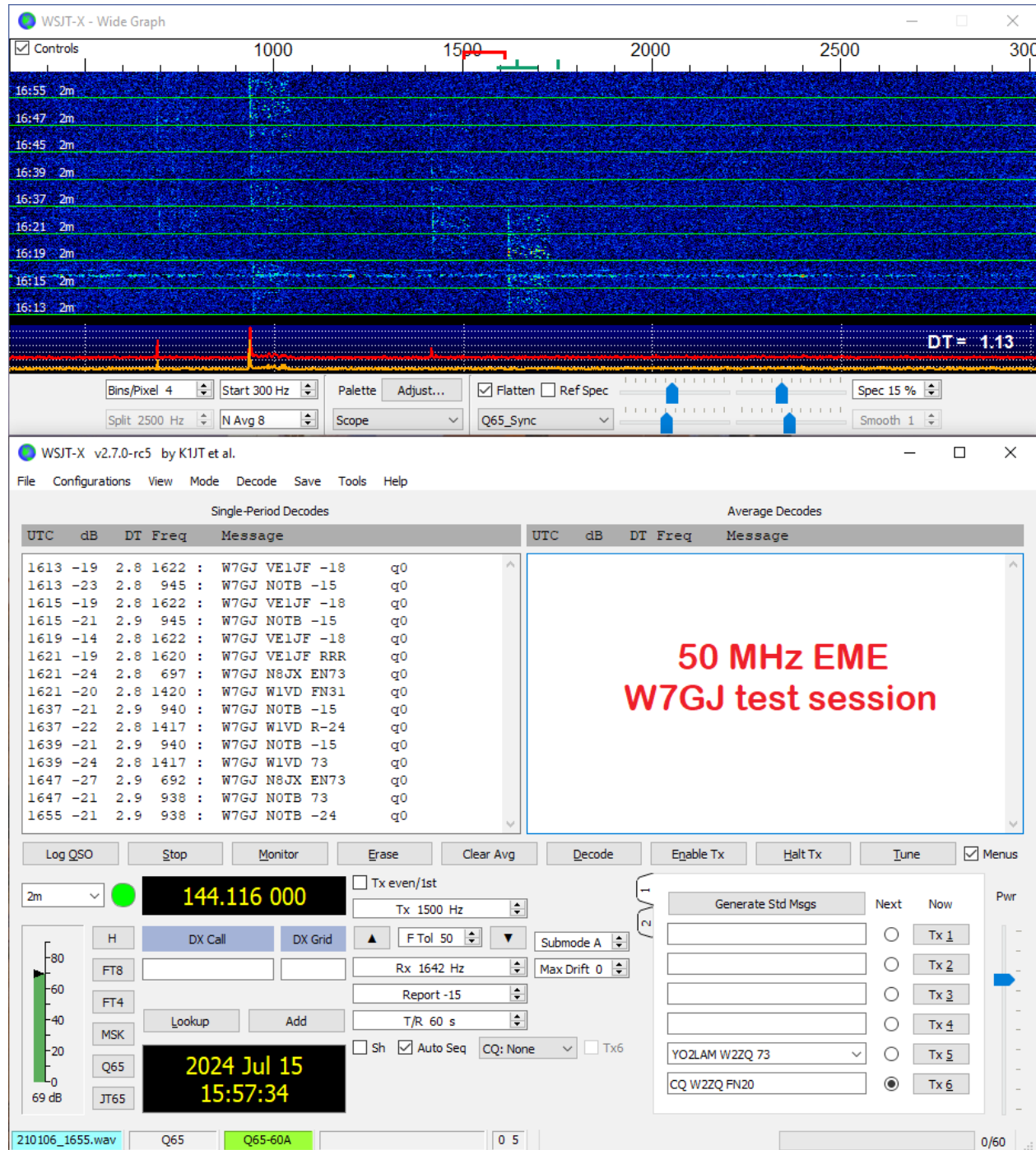
Software and Digi-Modes

WSJT-X

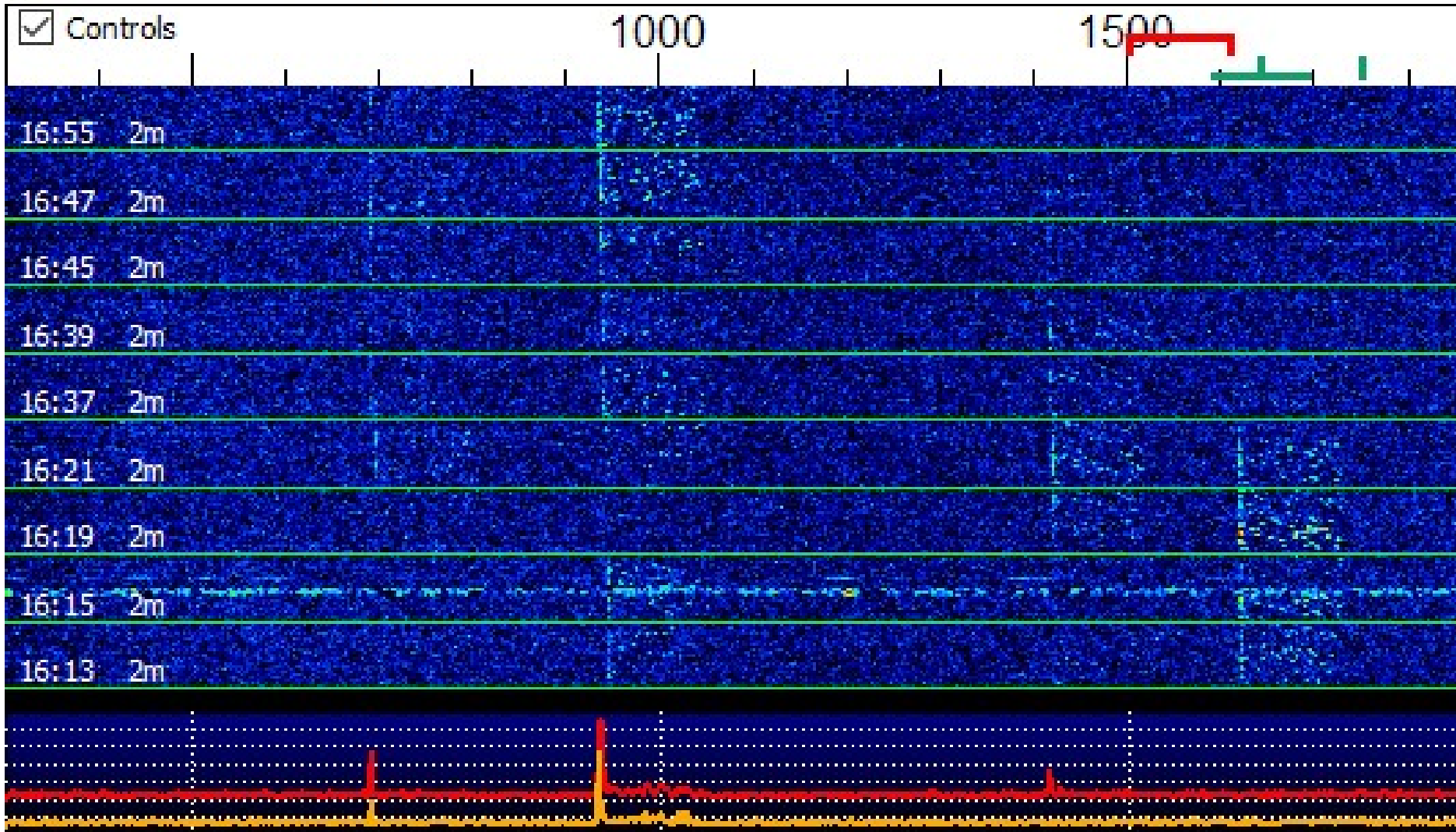
QMAP

Q65

WSJT-X




WSJT-X Waterfall



W7GJ works an EME pileup

UTC	dB	DT	Freq	Message
1613	-19	2.8	1622	: W7GJ VE1JF -18
1613	-23	2.8	945	: W7GJ NOTB -15
1615	-19	2.8	1622	: W7GJ VE1JF -18
1615	-21	2.9	945	: W7GJ NOTB -15
1619	-14	2.8	1622	: W7GJ VE1JF -18
1621	-19	2.8	1620	: W7GJ VE1JF RRR
1621	-24	2.8	697	: W7GJ N8JX EN73
1621	-20	2.8	1420	: W7GJ W1VD FN31
1637	-21	2.9	940	: W7GJ NOTB -15
1637	-22	2.8	1417	: W7GJ W1VD R-24
1639	-21	2.9	940	: W7GJ NOTB -15
1639	-24	2.8	1417	: W7GJ W1VD 73
1647	-27	2.9	692	: W7GJ N8JX EN73
1647	-21	2.9	938	: W7GJ NOTB 73
1655	-21	2.9	938	: W7GJ NOTB -24

WSJT-X Doppler Tracking

 WSJT-X - Astronomical Data

2024 Jul 15
UTC: 16:05:35
Az: 86.1
El: -34.2
SelfDop: 2821
Width: 13
Delay: 2.68
DxAz: 0.0
DxEl: 0.0
DxDop: 0
DxWid: 0
Dec: -18.7
SunAz: 141.7
SunEl: 67.2
Freq: 1296.1
Tsky: 4
Dpol: -49.8
MNR: 0.0
Dist: 401078
Dgrd: -2.2

☒ Doppler tracking

Doppler tracking

- ☐ Full Doppler to DX Grid
- ☐ Own Echo
- ☒ Constant frequency on Moon
- ☐ On DX Echo
- ☐ Call DX
- ☐ None

Sked frequency

Rx: 1,296.065 000
Tx: 1,296.065 000

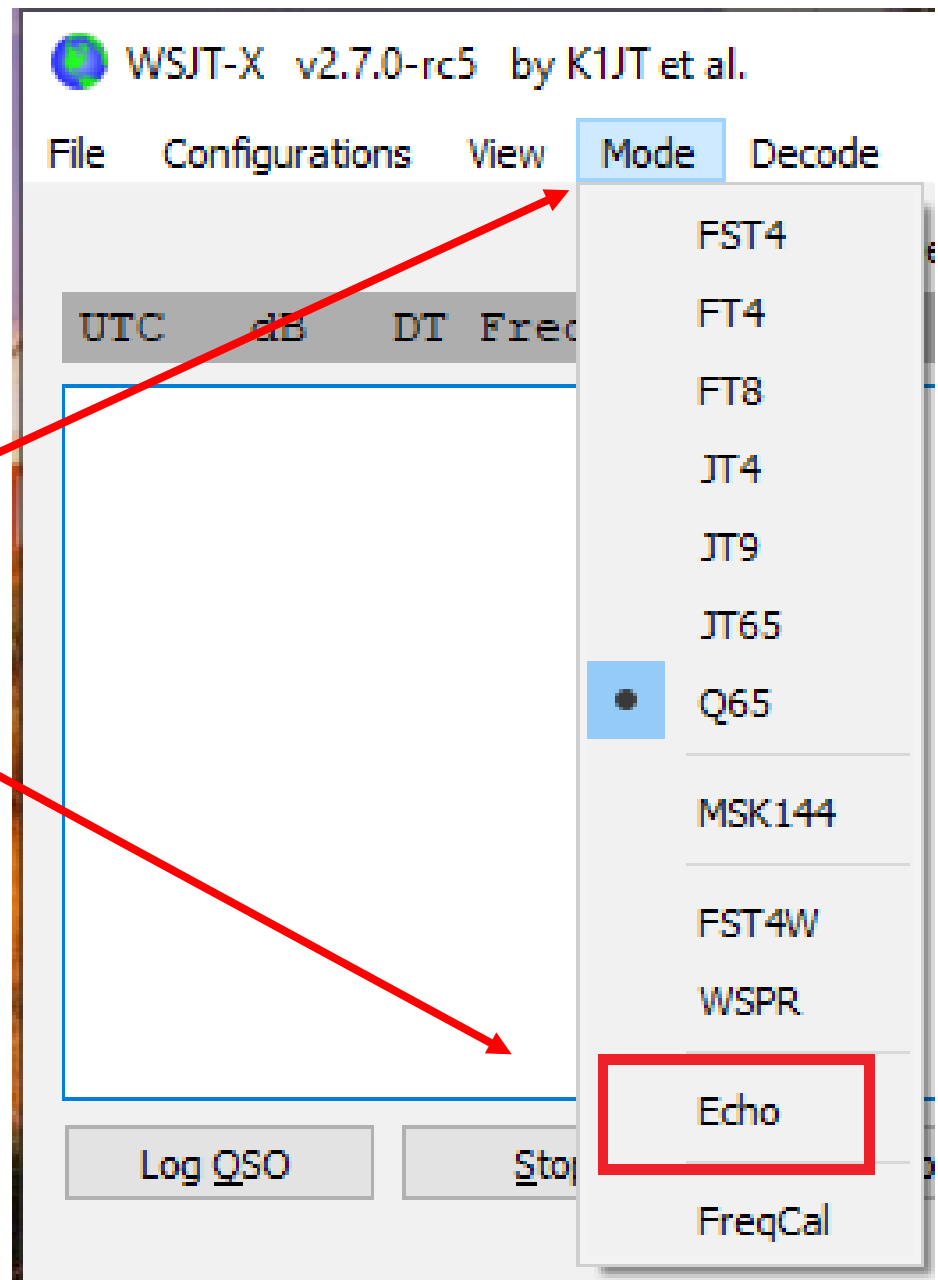
Press and hold the CTRL key to
adjust the sked frequency
manually with the rig's VFO dial or
enter frequency directly into the
band entry field on the main
window.

Echo Mode

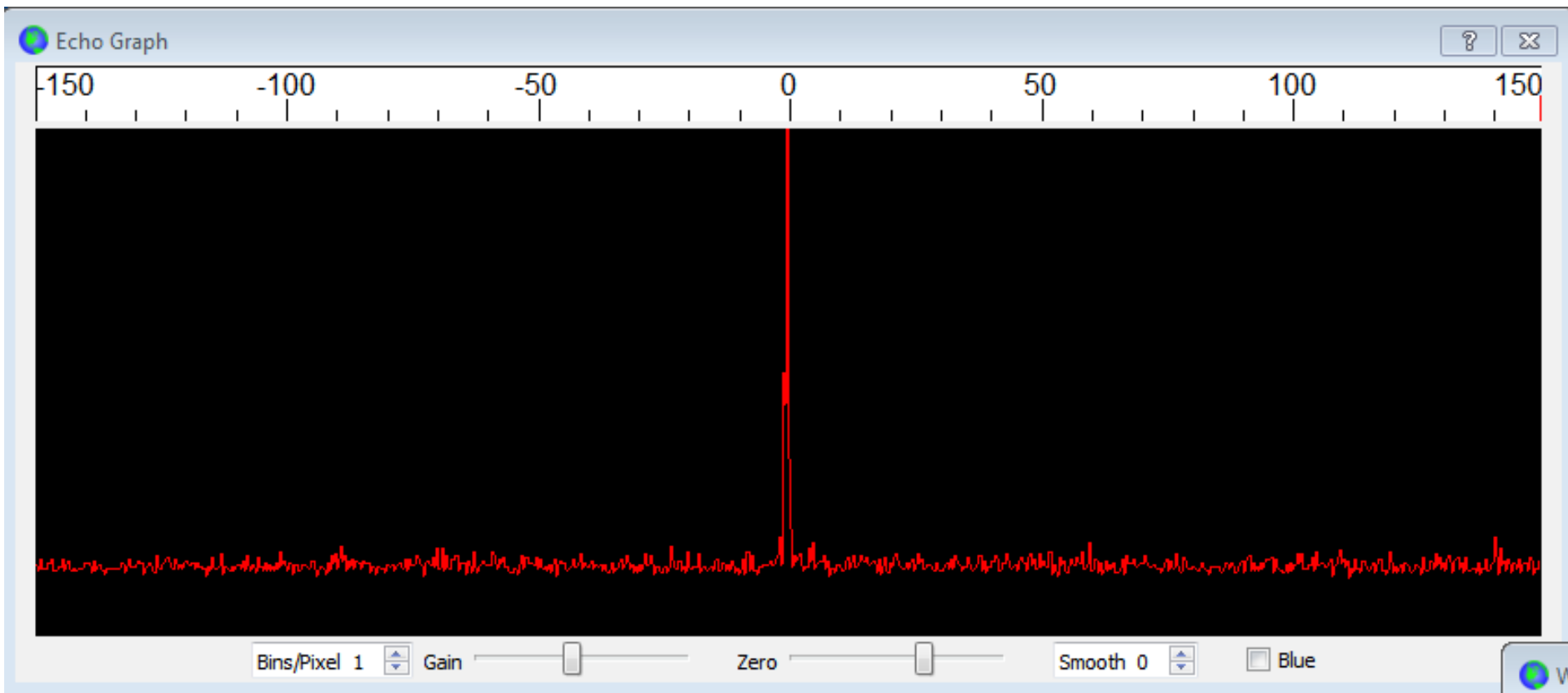
RIT 0 Hz

☐ Dither

WSJT-X Echo Mode

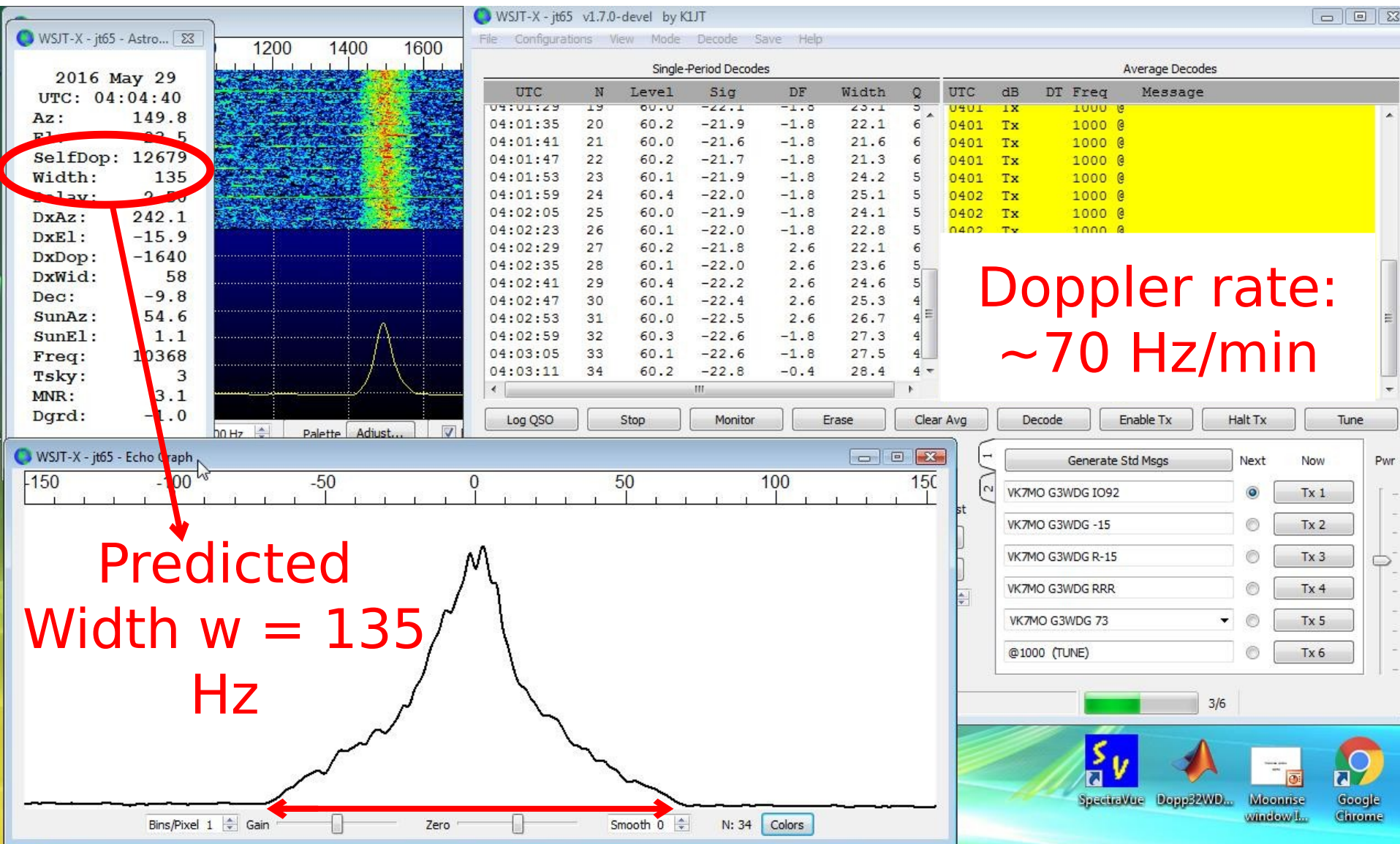


Echo Mode: K1JT, 144 MHz

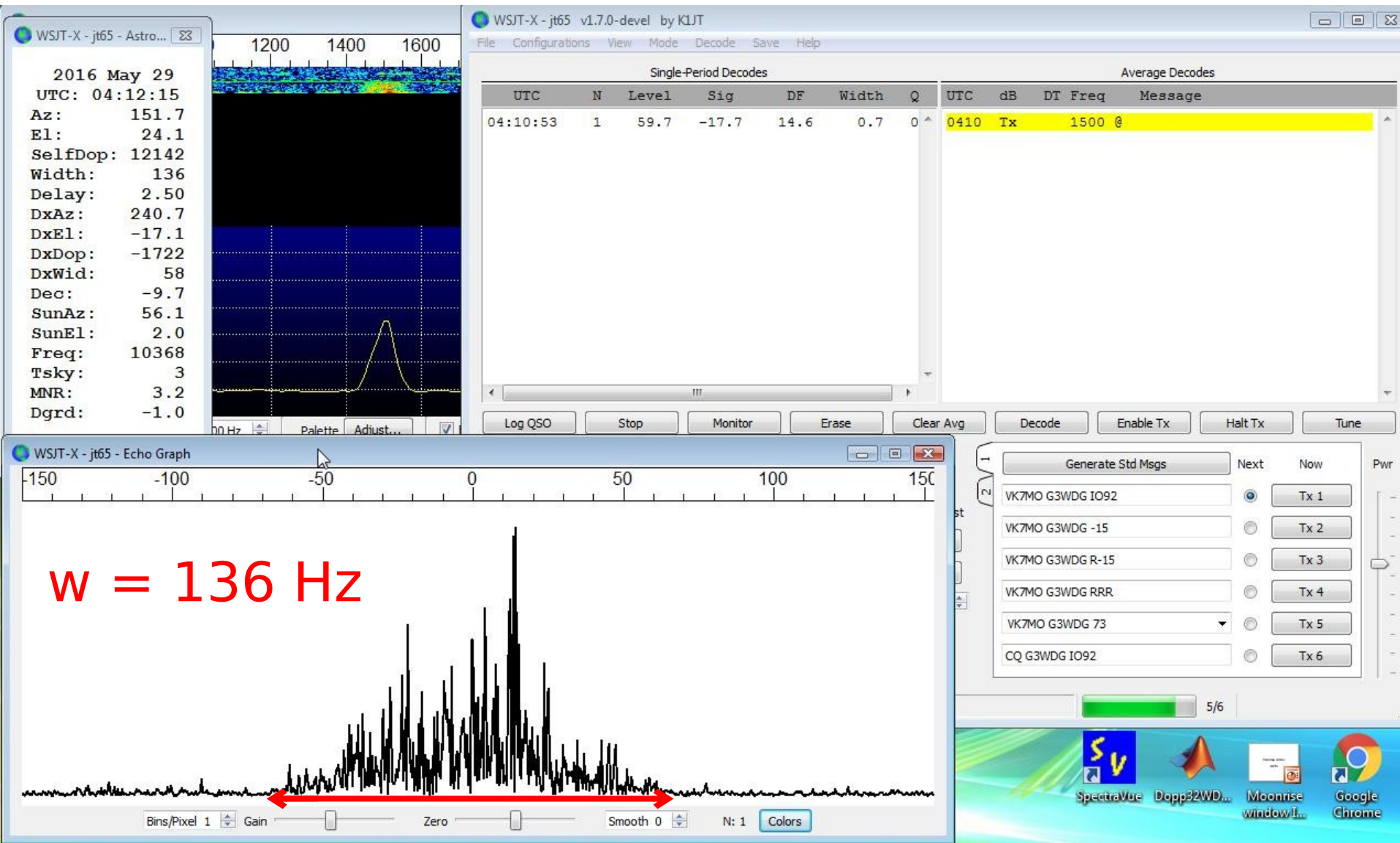


Doppler corrected; predicted spread 2.6
Hz

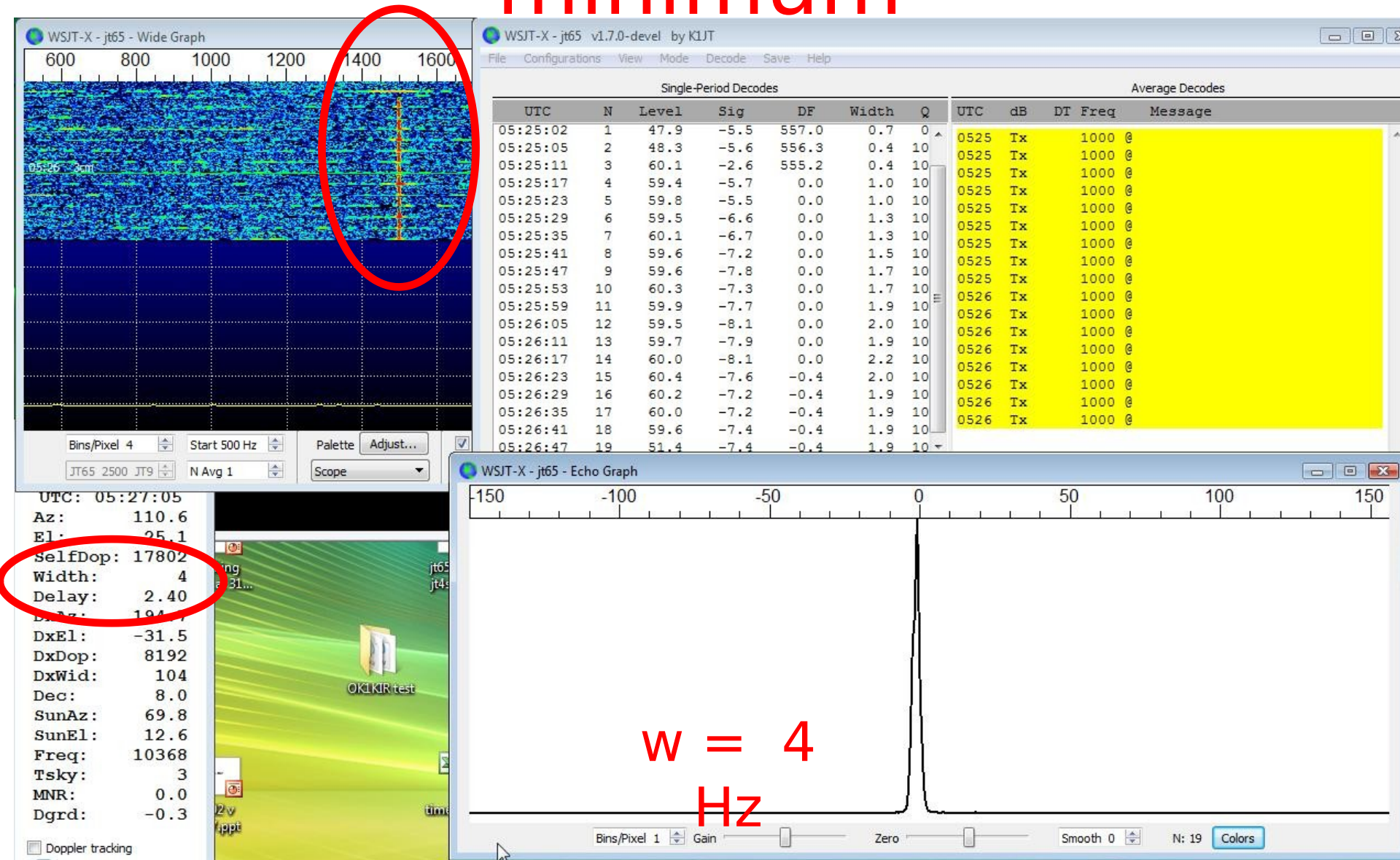
Echo Mode: G3WDG, 10 GHz



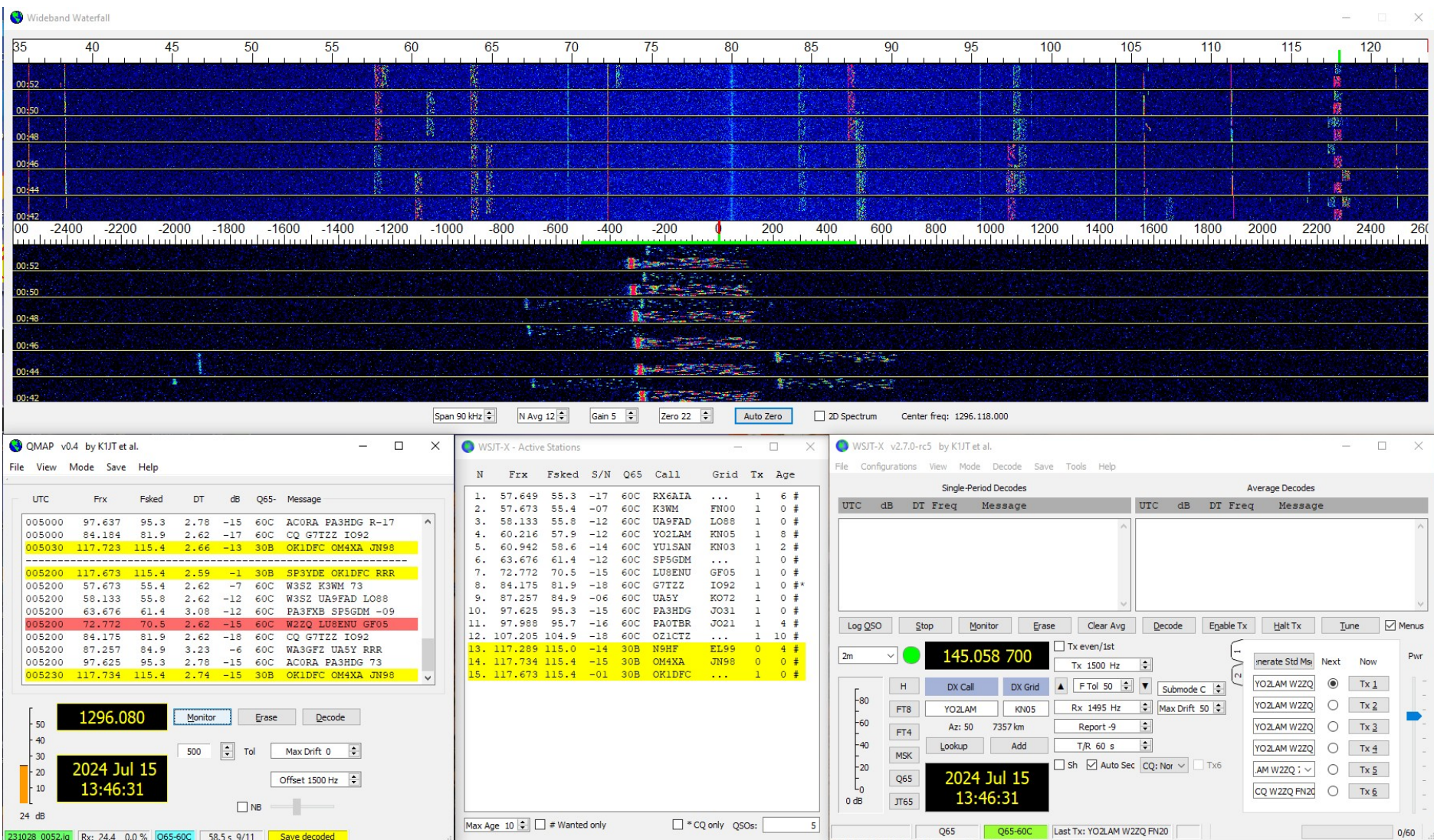
Single-pulse Echo, 10 GHz



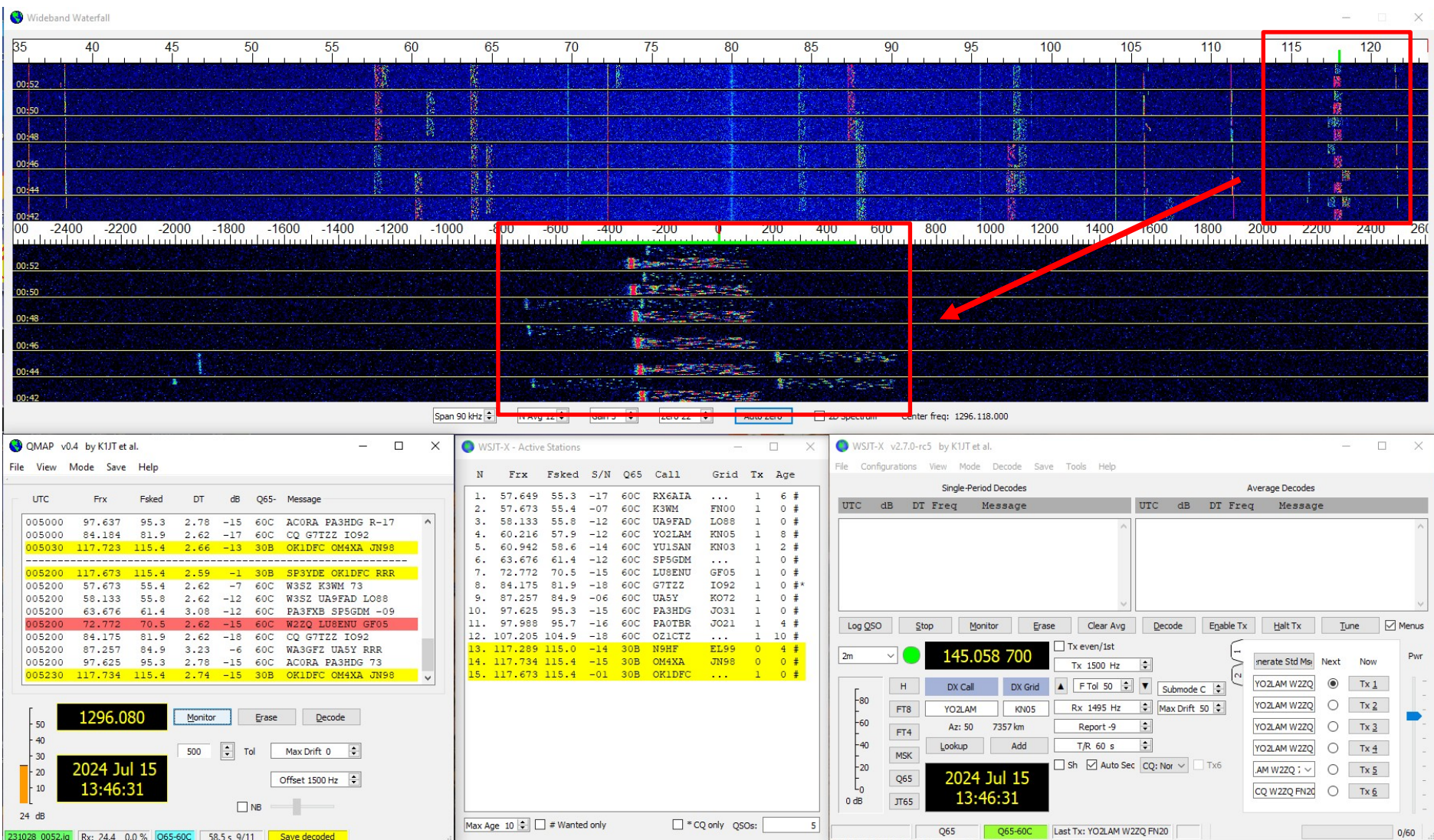
10 GHz echo at libration minimum



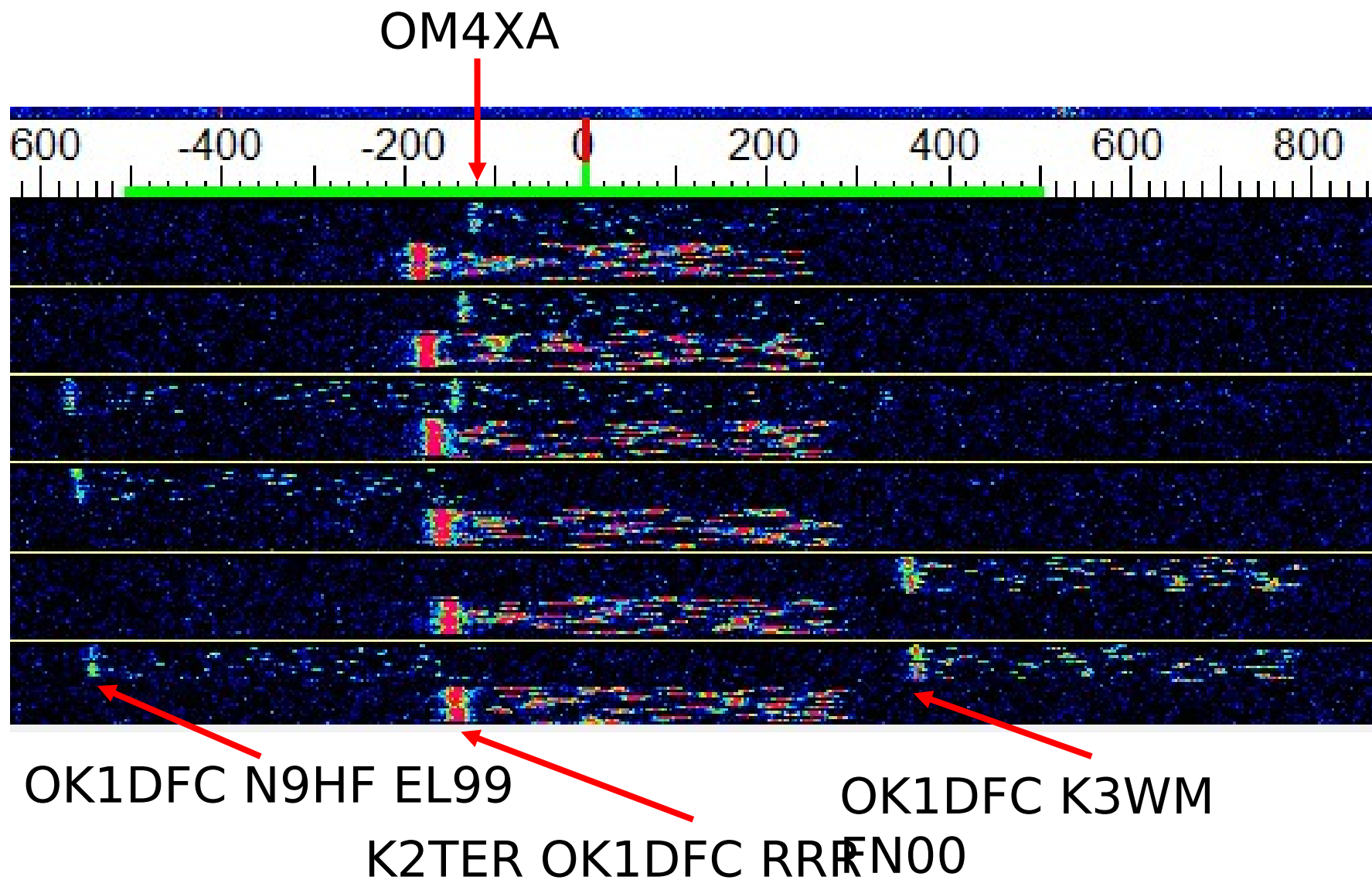
QMAP: Wideband Decoding



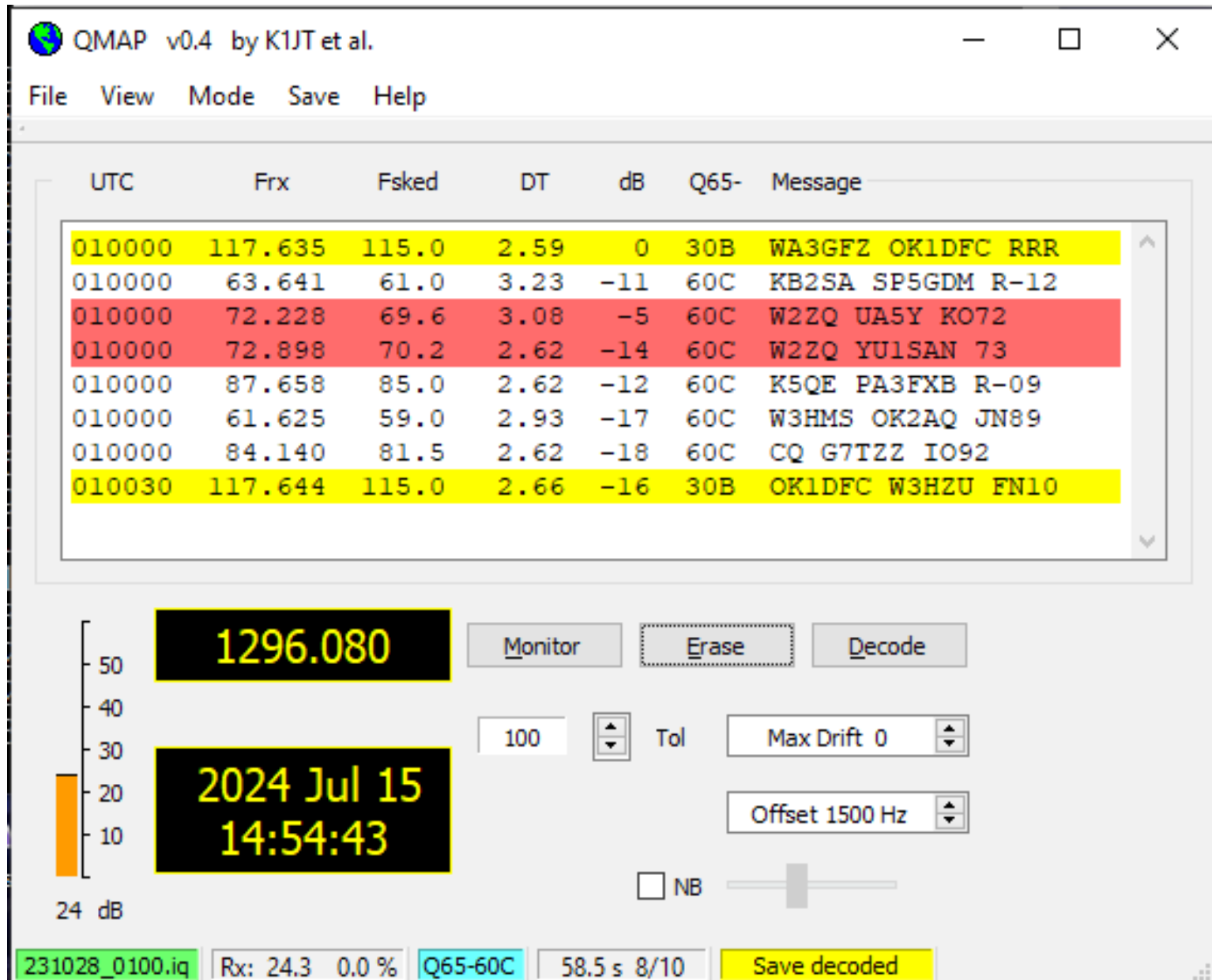
QMAP: Wideband Decoding



QMAP: High-resolution Waterfall



QMAP main window



WSJT-X: Active Stations

Click to
work a
station

WSJT-X - Active Stations									
N	Frq	Fsked	S/N	Q65	Call	Grid	Tx	Age	
1.	57.813	55.4	-07	60C	K3WM	FN00	1	0	#
2.	57.789	55.4	-17	60C	RX6AIA	...	1	6	#
3.	58.273	55.9	-12	60C	UA9FAD	LO88	1	0	#
4.	60.356	58.0	-12	60C	YO2LAM	KN05	1	8	#
5.	61.082	58.7	-14	60C	YU1SAN	KN03	1	2	#
6.	63.816	61.4	-12	60C	SP5GDM	...	1	0	#
7.	72.912	70.5	-15	60C	LU8ENU	GF05	1	0	#
8.	84.315	81.9	-18	60C	G7TZZ	IO92	1	0	#*
9.	87.397	85.0	-06	60C	UA5Y	KO72	1	0	#
10.	97.765	95.4	-15	60C	PA3HDG	JO31	1	0	#
11.	98.128	95.7	-16	60C	PA0TBR	JO21	1	4	#
12.	107.345	105.0	-18	60C	OZ1CTZ	...	1	10	#
13.	117.429	115.0	-14	30B	N9HF	EL99	0	4	#
14.	117.813	115.4	-01	30B	OK1DFC	...	1	0	#
15.	117.874	115.5	-15	30B	OM4XA	JN98	0	0	#

Max Age 10 ☐ # Wanted only ☐ * CQ only QSOs: 5

EME Digi-modes

- 50 MHz: Q65-60A
- 144 MHz: Q65-60B, JT65B
- 222, 432 MHz: Q65-60B
- 1296 MHz: Q65-60C Q65-30B
- 2.3+ GHz (depends on Doppler spread)
Q65-60C, -60D, -60E

Programming Details

- User interface: C++ and Qt
- Number crunching: Fortran
- Core developers: K1JT, G3WJS (SK), K9AN, IV3NWV, DG2YCB, N9ADG, G3WDG
- Open source: GPLv3 license
- Version control with git:

\$ git clone

<https://git.code.sf.net/p/wsjt/wsjtx>